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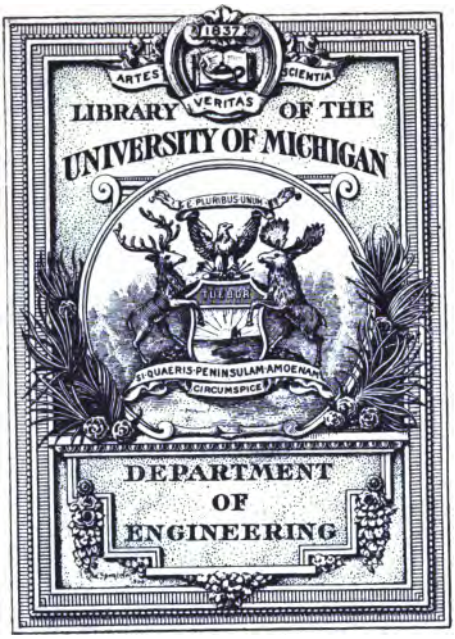

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SUPPLEMENT TO No. 27.

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REPORT

OF

BOARD OF ENGINEER OFFICERS

ON

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SPECIFICATIONS

FOR

ELECTRIC LIGHT AND POWER INSTALLATIONS

OF

SEACOAST BATTERIES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1902.

SUPPLEMENT TO NO. 27.

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1902.

WAR DEPARTMENT,

Document No. 125

(Supplement).

OFFICE OF THE CHIEF OF ENGINEERS.

OFFICE CHIEF OF ENGINEERS,
U. S. ARMY,
February 10, 1902.

Respectfully submitted to the Secretary of War.

The within report of the Board of Engineer Officers, constituted by Special Orders, No. 17, Headquarters Corps of Engineers, May 3, 1901, contains a report upon changes in Professional Papers, Corps of Engineers, No. 27, "Report of Board of Engineers on Specifications for Electric Light and Power Installations of Seacoast Batteries," made necessary on account of the greatly increased size of the units now proposed for use and the grouping of all the plant into a central station with a triple duty to perform—post lighting, battery lighting and power, and searchlight.

It is recommended that the report of the Board be approved, and that, on account of its interest to engineer and artillery officers, 500 copies be printed at the Government Printing Office, as an Appendix to Professional Papers, Corps of Engineers, No. 27, and furnished for the use of this office on the usual requisition.

G. L. GILLESPIE,
Brig. Gen., Chief of Engineers,
U. S. Army.

WAR DEPARTMENT, *February 15, 1902.*

Approved as recommended by the Chief of Engineers.

WM. CARY SANGER,
Assistant Secretary of War.

REPORT.

UNITED STATES ENGINEER OFFICE,
New London, Conn., January 15, 1902.

GENERAL: 1. The Board of Engineer Officers constituted by Special Orders, No. 17, May 3, 1901, has the honor to submit the following report directed especially to so much of the instructions of the Chief of Engineers as requires the Board to consider and suggest "such changes in Professional Papers, Corps of Engineers, No. 27, as may be necessary on account of the greatly increased size of the units now proposed for use, and the grouping of all the plant into a central station with a triple duty to perform—post lighting, battery lighting and power, and searchlight."

2. The controlling conditions recognized by the former Board, and which the installation proposed in Professional Papers No. 27, was designed to meet, were: Intermittent service, inexpert and noncontinuous attendance, and exposure of generator and switch board apparatus to excessive moisture.

3. The foregoing conditions apply to the emplacement service alone, or possibly to that service combined with searchlights. The introduction of garrison service reverses all of them; and, with garrison lighting included, the controlling conditions are: Continuous service, expert and continuous attendance, dry power rooms.

4. The third of these new conditions follows from the first. The heat radiated from a plant in daily use will keep any bomb-proof structure dry, if percolation be prevented.

5. With these changes of governing conditions the considerations held in view in Professional Papers No. 27 as influencing the choice of mechanical and electrical details require modification and rearrangement. Economy of operation and commercial efficiency become matters of great importance, and first cost one of lesser consideration. Simplicity of design and uniformity between plants at different stations, so desirable in general and so essential with the inexpert attendance which intermittent service implies, are no longer necessary. The expert supervision which continuous service imposes will allow the use of more complicated machinery to meet the special conditions of any locality than would be deemed permissible in a plant intended for intermittent use only, and thus enables the engineer to devise a plant

for each locality which will best meet the requirements of that locality without attempting to secure uniformity with plants at other localities where the conditions are not the same. Uniform treatment is probably impracticable under present requirements.

6. To specify the principal changes contemplated in the foregoing discussion: A more efficient boiler than the vertical type will often be required; horizontal or vertical engines may be employed, compound or condensing, if found advisable, and direct connection of engine and generator, though still preferable, is not essential. Belt driving may be found advantageous where the conditions favor a higher speed of generator than is practicable with direct connection, as in the case of the A. C. D. C. generator hereinafter referred to.

7. Great difficulties will be encountered in some cases in the attempt to furnish adequate garrison service at reasonable cost by the use of direct current. These difficulties may be overcome with ease, and the cost decreased, by the introduction of alternating current for garrison service, for which it is well adapted. The condition is imposed that if alternating current be adopted for the garrison service it shall be supplied from the same plant as the emplacement and searchlight services, which require direct current. One way to accomplish this result is to introduce a motor generator into the garrison feeders, taking direct current from the generator and delivering alternating current to the line at 1,000 or 2,000 volts, according to the distance of transmission. Static transformers, according to usual commercial practice, will reduce the voltage to 110 for delivery to the lamps. The objections to this are the cost and upkeep of an additional machine, the motor generator, and the liability of derangement of the lighting system by irregularity or failure in its operation. The losses in the system will be those of motor generator plus line losses plus transformer losses at the other end.

8. The same result, direct and alternating current from the same plant, may be reached by the employment of a rotary converter instead of the motor generator. This machine has but one set of coils, takes direct current from the generator at 110 volts, and delivers alternating current at 77 volts with very slight losses. A special static transformer will be required with the proper ratio to raise the voltage to that determined upon for the line and standard static transformers at the other end to reduce the voltage to 110 for delivery to lamps. The losses in such a combination will be that of the converter, very small, plus the losses in the line and two static transformers, probably 11 per cent in the apparatus plus the loss allowed in the line. The objection to an additional machine applies here also.

9. The two methods above outlined are in commercial use. A third method, which has been investigated so far as possible with the time at the Board's disposal, depends upon the employment of the same machine as in the second method, but used in a different way. The

rotary converter, instead of receiving and being driven by direct current at 110 volts, and delivering alternating current at 77 volts, may be itself driven by a prime mover, in which case it becomes an A. C. D. C. generator, giving direct current from the commutator, and alternating from the collector rings, the former at 110 and the latter at 77 volts. Less the small current required to excite the fields, the entire capacity of the machine may be taken from either side, or this capacity may be divided in any desired ratio between the two. Constructive conditions appear to demand that this machine shall be driven at a higher speed than is possible with direct connection; and hence, if this method be adopted, belt driving follows as a necessary consequence. This, as before intimated, is not considered a serious objection under the circumstances of the new installations. With the A. C. D. C. generator a special static transformer will be required to step up, and standard ones to step down, as in the second method. This system saves one machine. The losses will be about 10 per cent less than in the second method.

10. Small machines of this type are in use in several of the university laboratories, and a number varying in capacity from 200 to 500 K. W. capacity, and aggregating 4,500 K. W., have been installed for commercial purposes by one manufacturer, and are in successful operation. The same company is now building machines aggregating 4,000 K. W. They are somewhat larger, heavier, and more expensive than D. C. machines of the same capacity. In addition to this, the belt connection will require considerably more floor space than the engine type. Apparently, the only open question is the effect of varying loads on the direct side upon the regulation of the alternating side. But, as in the installations now discussed the combined load will rarely, if ever, occur, this question is secondary in importance.

11. In a former report the Board recommended that the use of boosters be held in view to effect a reduction of copper over long transmission lines. The booster is a motor generator with direct current on both sides. The secondary, or generator, side is wound for low voltage, and, being in series with the main generator, adds its voltage to that of the dynamo. When a booster is employed it may be given a secondary voltage equal to the drop in the feeder, so that the voltage delivered to the mains will be that of the dynamo. The booster loss will be the product of the secondary voltage and the feeder current, divided by the efficiency coefficient of the booster.

12. All the systems described permit the use of the accumulators for post lighting. In the first, second, and fourth the accumulator replaces the D. C. generator. In the third system the A. C. D. C. generator becomes a rotary converter, as in the second system, its direct side taking current from the accumulator. In this system the accumulator is not a true reserve for the generator, but only for the

prime mover, and, while the accumulators are supplying the post, the generator can not be used for any other purpose. The system is slightly less flexible than the others, but in every other respect is probably superior.

13. In the opinion of the Board the use of accumulators for garrison service, if begun, will, save in exceptional cases, be discontinued as soon as its cost is appreciated.

14. In view of the wide range of choice permissible under the new conditions, the Board finds it impracticable to frame specifications for every kind of apparatus that may be preferred by district officers, and limits itself to such as, in addition to those covered in Professional Papers No. 27, are most likely to be adopted.

15. A water-tube boiler has many advantages in economy of fuel, safety against serious explosions, accessibility for inspection and repair, and as conforming to the practice now almost universal in equipping commercial plants, and will probably be more frequently called for than any other type. Each of these boilers is so specialized in design and construction that specifications in the ordinary sense can not be drawn. To illustrate: It is impracticable to state the number of square feet of heating surface that should be provided per horsepower of boiler, since the efficiency of the heating surface varies with the different makes of boilers. It is impracticable to state a definite ratio between the grate surface and heating surface, since this also varies with the kind of coal used, the degree of efficiency of the heating surface, and the size of boiler. A large water space, while always a good thing, may not of itself be of sufficient value to reject a boiler otherwise acceptable. The same may be said of the steam space, and a disengaging surface which would be ample for a boiler of strong circulation would be much below that required in a boiler of sluggish circulation.

16. The Board subjoins a description of the fundamental feature of design and construction which any good boiler of this type will fill, and certain data from reliable authorities which may aid in designing and proportioning the various elements of a plant. The safest course appears to be to confine the selection to the best-known types of water-tube boilers, which have proved their fitness in like service, to specify the required performance in evaporation units and per cent of efficiency on coal, and to prescribe the maximum entrainment of steam which will be tolerated. The specifications submitted herewith, which are intended to be full as regards the character of the material to be used in constructing a boiler, are silent upon a number of important points which affect its steaming qualities, but which it is not possible to cover by specific stipulations. The reputation of the boilermaker must be relied upon to secure a fulfillment of these essential and nonstipulated conditions. The specifications being general in their nature, no stip-

ulations are included regarding the height, length, or width of the boiler. If the space available is contracted as to its height, width, or length, the course recommended is to select at the start a special make of boiler which is known to fit the space available and which will conform to the general specifications as to straightness of tubes, ease of repair, quality of material, etc.

17. When water-tube boilers are used, it will be prudent to keep on hand enough of the small parts of special construction to make the plant independent of supply from the builder for a reasonable period.

18. For generating sets the present practice favors the horizontal, direct-connected, center-crank multipolar type. For plants which are to be used in daily post lighting, if the feed water be scant or poor, and condensing water can be obtained, the compound condensing engine may be advisable. A noncondensing compound plant suits a case where water is scarce and fuel costly, and the simple engine is well adapted to plants intended for occasional use only.

19. A committee of the American Society of Mechanical Engineers on the standardization of engines and dynamos recommends speeds as follows:

	Revolutions per minute.
For 25 K. W. unit	310
For 35 K. W. unit	300
For 50 K. W. unit	290
For 75 K. W. unit	275
For 100 K. W. unit	260

20. For a simple engine plant a boiler pressure of 100 pounds per square inch is usual; for a compound noncondensing plant, 125 pounds; for compound condensing plant, 150 pounds.

21. The condition that the supply of current to searchlights and emplacements should be as free as possible from interruption on account of derangements or accidental breakage of machinery, suggests extraordinary care in selecting the principal elements of the generating plant, such as engine, dynamo, and boiler, from the very best types obtainable in the market without special reference to economy in first cost.

22. The Board recognizes that no specifications can be framed, nor tests prescribed, which will infallibly reject an inferior steam engine. Different practice in minor details, and in some cases radical differences in principles of designing, are found among the best builders, and to so great an extent as to make it impracticable to draw minute specifications. Each builder regards the peculiarities of his engine with especial pride and attempts to make their alleged superiority a trade asset. The best builders are reluctant to vary these details to suit specification requirements, and if they do so the cost is very great.

23. General requirements, on the other hand, as to speed regulation, steam consumption, and other tests that are practicable, can be easily fulfilled by makers of low-priced engines, who would, however, not be able to make good a guaranty upon other essential points, such as correctness of design, proper proportion of parts to resist their strains, quality of material used, perfection of workmanship, etc., which it is not possible to cover by specifications. These can be determined only by the reputation of the maker.

24. The same remark applies with even greater emphasis to the selection of dynamos and motors, many essential features of which are in hidden construction, and can not be verified by inspection of the completed machine. The reputation of the maker must be relied upon even to a greater extent than in the case of the engine and boiler as a guaranty that the machine delivered will be all that is desired.

RESERVES.

25. As stated in the report of the Board, dated June 19, 1901, the accumulator reserves should be of capacity to supply the searchlight service for one hour at a nondestructive rate of discharge, which the Board has experimentally determined may safely be taken at four times the normal rate, or to supply the lighting load of the emplacements for eight hours at normal rate. The one of these conditions which calls for the larger accumulator should determine the minimum size.

26. Recent experience in heavy mortar firing leads to the conclusion that the largest glass jars now made will be uninjured by concussion, and may safely be used; so long as glass receptacles can be obtained in the market they should be preferred to any other. This extension of the use of glass jars is made to facilitate inspection of the elements. The same desirable object may be further promoted by allotting ample space to the accumulator, and arranging the cells in a single tier vertically, and, so far as possible, in single rows horizontally. While this open arrangement is of distinct value and advantage, it is not sufficiently so to demand the construction of a larger room if a smaller one already built is available.

27. The limitation to Faure and Plante plates is justifiable at present, but should be considered as applying only to the present state of the art.

SWITCHBOARDS.

28. The present type plant consists of a single generator with its panel and one or more accumulators with a panel for each. The generator panel distributes current to the accumulator panels, and the latter, receiving current from the generator, distribute it to the various circuits and to the accumulator, or, disconnected from the gener-

ator, take current from the accumulator and distribute it to the various circuits. There appears to be no reason for changing this system which has been carefully worked out and has given satisfactory results.

29. The proposed type plant is to consist of duplicate generators with distribution to searchlight and garrison buildings in addition to emplacements. The two generators are supposed to be equal in capacity to the normal load, with overload capacity sufficient to take care of the variations, and the second generator is provided as a mechanical reserve. It is considered undesirable to permit the generators to be operated in parallel, since each being a mechanical reserve for the other, they should not be exposed to a common danger; but, with their circuits kept separate, arrangements are proposed for working them in combination in case the demand exceed the capacity of one, each, when so working, to take care of a distinct part of the load. What is required is, first, to so modify the generator switchboard that it shall permit either of the generators to supply current to several of the accumulator panels, permit one to supply certain feeders, and the others to supply certain others, while making it impossible to throw them both simultaneously on to the same line; and, second, to modify the accumulator panels as may be necessary to provide for such of the requirements of garrison and searchlight services as are not met by the present type. The restriction as to parallel working applies only to such units as are duplicated for reserves; if one of these be again divided for economy of operation, or other reason, the two parts may be operated in parallel on a common panel.

30. It is proposed to provide each half of the generating plant with its own panel carrying the measuring and indicating instruments and safety devices required for its operation, and about one-half of the feeder switches. The two panels set side by side will form the generator switchboard. The bus bars will be placed sufficiently out of alignment, so that each pair can be extended across the other panel, connecting with the distributing switches thereon, but not with any other apparatus. The feeder switches will be double-pole double-throw to operate on either set of busses. They should be provided at the hinge with a spring holding them firmly in the neutral position to permit of mounting them vertically instead of horizontally, which will greatly reduce the space required and simplify the connections. A single motion will throw any feeder on to either of the generators, or from one to the other. Either generator may be operated on any circuit, or on all of them, and both may be operated together, each supplying any desired circuits, but it is not possible to connect the two generators on the same circuit. A diagram showing two such panels side by side is herewith.

31. Where the number of circuits to be operated is so large that the generator panels do not afford convenient space for mounting the

feeder switches, the latter may be placed on a separate distribution panel, and the generator panel be reduced to the measuring instruments, and a single switch connecting it with the distribution panel. This arrangement is also shown on a tracing herewith.

32. Two cases not covered by the type accumulator panel must be provided for. The first is to operate the searchlight from the generator while the accumulator is discharging. This may be done by using a double-throw switch for the searchlight circuit, connecting with the busses in one position, and in the other with terminals branched from the generator leads at their entrance on to the board. By such an arrangement it will be found possible in many cases of long transmissions to greatly reduce the size of feeders using the accumulator exclusively for supplying lights, and throwing into the line a portion of the large drop which occurs in charging accumulators and running searchlights.

33. The second case will arise if the maximum garrison load is greater than the capacity of the generators and it is desired to put on the accumulator in parallel to take the peak. This case, it is thought, will seldom arise, and should be regarded as exceptional. The desired arrangement may be made by connecting the right-hand terminals 2 and 3 of the lower blade of the triple-pole switch through a single-pole switch conveniently placed. When the extra switch is open, the generator and accumulator can not be put on the busses at the same time. When the extra switch is closed, and the triple-pole switch thrown to the position of discharge, the generator and accumulator will be in parallel on the busses, and their joint capacity will be available. The regulation of voltages under these circumstances will require constant and expert attention, and such attention should give reasonable security from the dangers which the break 2–3 in the generator leads was designed to obviate.

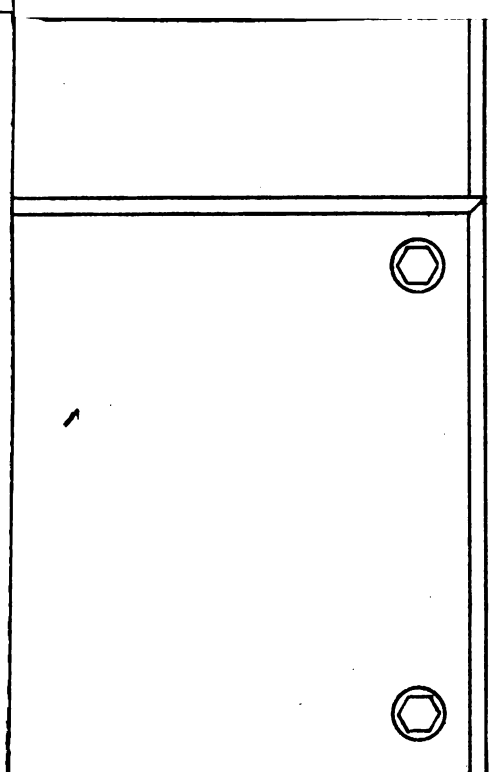
34. Sketches showing the proposed modifications of the type panels are herewith.

35. In switchboard construction commercial practice may be followed as to metals employed for fastenings, as in paragraphs 46–49, 63 and 100, and for some other purposes not involving electrical circuits, as the instrument cases, paragraphs 57 and 79. The widths of panels can not be fixed.

RHEOSTATS.

36. In view of the difficulties which have been experienced in the use of metallic rheostats from corrosion, overheating, and mechanical derangements, the Board suggests for the consideration of district officers the advisability of substituting water rheostats for metallic ones for handling large main currents. The principal requisites of a water rheostat are noncorrosive plates, preferably carbon, with closely

Senior Member.



pectfully submitted with report
Board of Engineer Officers
ed. Jan. 15. 1902

Major Corps of Engineers U.S.A.
Senior Member.

regulated motion to control both the distance from each other and their immersion in the liquid, which should be pure water slightly acidulated. The degree of acidulation will exercise a marked influence in the resistance of the rheostat and may be utilized with advantage in that respect. Such a rheostat should be placed where fumes can escape easily to the air and the material for its replenishment should be kept close at hand available for instant use, with arrangement to operate it from the usual position at the switchboard. A water rheostat well constructed and in good working order will give closer regulation than can be obtained from metallic resistances arranged in steps.

WIRING METHODS, LAMPS, AND MOTORS.

37. So far as applied to emplacement lighting, the requirements as laid down in Professional Papers No. 27, under these several headings, need no special change, but with the electric plant made to embrace post and building lighting, larger cables will be needed and some modification of specifications will be necessary.

38. As the cables increase in size, the thickness of insulation being constant, the same insulation resistance can not be obtained for all sizes, and either this resistance should be varied with the size of the cable or the thickness of the insulation should change. With $\frac{5}{32}$-inch rubber insulation a No. 14 wire will show a resistance of 1,800 megohms per mile, at 15.5° C., under 1,000 volts pressure when tested after twenty-four hours in sea water and one minute's electrification, whereas, as under the same condition, 1,000,000 c. m. cable could not be expected to show a greater safe resistance than about 400 megohms per mile.

39. For all emplacement lighting and searchlight work and for other purposes, when laid in ground which can not always be kept drained, due to the action of tides or other causes, the very best of insulating material should be required; that is, rubber, and it should be $\frac{5}{32}$-inch thick. For post purposes, however, except where water is to be encountered, as noted above, rubber insulation $\frac{3}{32}$-inch thick will be ample; the safe resistance will then vary from about 1,200 megohms per mile for No. 14 cable to 200 megohms per mile for 1,000,000 c. m. cable.

40. The use of paper insulation on lead-covered cables to be placed in conduits or trenches is worthy of consideration in connection with post and building lighting, particularly if alternating current be employed.

41. The use of steel conduits for interior wiring of emplacements is no longer deemed essential, though the requirements which originally led to their adoption still obtain, namely, that the installation shall be moisture proof and air-tight; for example, in the opinion of the Board satisfactory wiring can be done by the employment of lead-covered

cables held in place by molding or other supports entering lamp and outlet boxes by wiped joints or other water-tight connections, the boxes themselves to be of the air and moisture proof type.

Very respectfully,

SMITH S. LEACH,
Major, Corps of Engineers, U. S. A.
S. W. ROESSLER,
Major, Corps of Engineers, U. S. A.
GEO. W. GOETHALS,
Major, Corps of Engineers, U. S. A.

Brig. Gen. G. L. GILLESPIE,
Chief of Engineers, U. S. A.

SPECIFICATIONS FOR WATER-TUBE BOILERS SUITABLE FOR DETACHED POWER HOUSES OF SEACOAST FORTIFICATIONS.

1. The boiler must be of the water-tube type, with straight tubes.

2. Steam will usually be taken at 100 pounds pressure, but the boiler must have a safe working pressure of 150 pounds per square inch, and after erection must be tested and made tight under 250 pounds hydrostatic pressure.

3. The boiler must be capable of delivering ——— (K. W. × 84 for simple high-speed engines; K. W. × 70 for compound noncondensing engines; K. W. × 56 for compound condensing) units of evaporation per hour without being forced, with an entrainment of moisture not to exceed 1 per cent and at an efficiency to be not less than 65 per cent.

4. The boiler must have adequate steam and water spaces, and disengaging surface to afford a reasonably steady water level and to insure a supply of steam at all times with an entrainment of not more than 1 per cent under extreme variations in load. The proportion of grate to heating surface must be the most economical for the size of boiler and best adapted to the use of ——— coal.

5. All parts of the boiler must be accessible for inspection, cleaning, and repairing, and it must be practicable to remove and replace any single tube or tube unit without disturbing any other. Special provisions must be made by which soot and ashes can be readily and thoroughly removed from the tubes. Boilers of a height greater than ten (10) feet when fully set which require cleaning from the top will not be acceptable.

6. It must be practicable to plug a damaged tube without impeding the circulation through any other tube.

Rivets must be sized and spaced in accordance with the requirements of the Board of Supervising Inspectors of Steam Vessels for steel plates and steel rivets. The longitudinal shell seams must be double-riveted.

7. No screwed joints will be permitted where exposed to fire or heated gases.

8. The boiler must have a flanged steam outlet for steam pipe, said flange to be fitted with bolts and faced and drilled true to receive companion flange on steam pipe. If the safety valve has an independent connection to the boiler, the steam-nozzle area must be equal to that of the standard delivery pipe corresponding to the capacity of the boiler; otherwise the area must be approximately equal to the combined areas of the safety valve and delivery pipe.

9. The boiler must be provided with a dry pan or dry pipe, with baffle plates and a mud drum.

10. All parts of the boiler subject to tensile strain from steam pressure, and not specifically excepted hereinafter, must be of mild non-tempering open-hearth steel of 55,000 to 60,000 pounds tensile strength, with not less than 56 per cent of ductility as determined from contraction of area at point of fracture, and by an elongation of 25 per cent in a length of eight (8) inches.

11. The tubes must be of best wrought iron, lap welded, or of seamless cold-drawn steel. They must be straight, free from rust, injurious sand marks, blisters, scales or cracks, laminations, and injurious defects generally, and each tested to 500 pounds internal hydrostatic pressure.

12. Cast iron may be used for hand-hole plates, crabs, yokes, etc., headers, and mud drums.

13. When cast iron is used in parts of boiler subject to tensile strain from steam pressure, it must be the best car-wheel mixture, charcoal cold-blast variety; and all such parts must be capable of standing an internal hydrostatic pressure of 400 pounds per square inch.

14. Rivet holes may be drilled or may be punched one-eighth inch below size and reamed. Reaming must be done in place, the parts being assembled with bolts and all holes brought fair. After drilling or reaming the burr must be carefully removed. All holes must be brought fair by reaming before the rivet is inserted; a drift pin must not be used. All rivets which can be reached by a machine should be power driven. All straight edges must be planed, and all circular edges turned smoothly and to the proper bevel. Irregular or double-curved edges must be neatly chipped to bevel before seaming. Seams must be caulked with a round-pointed tool, shell seams inside and out.

15. Press work is preferred for all flanging, but hand work is permitted if done exclusively with wooden mauls.

16. The tubes must be expanded into headers in a workmanlike manner through drill holes slightly countersunk on both sides.

17. A complete boiler setting must be provided, including: complete iron fronting with standard fire and ash pit doors; iron doors and frames for all apertures in setting; buck stays, tie and anchor

rods, anchor plates, castings, special tiling and other material required for the permanent setting of the boiler; an approved shaking bar grate known to give satisfaction with ——— coal; one set of firing tools, including slice bar and hoe; scraper and handle for cleaning of inside of tubes; pipe and best 3-ply rubber hose of requisite length and necessary fittings for use in freeing tubes of soot and ashes; all wrenches required for the ordinary adjustment of the boiler; one safety valve of approved design having one-fourth of one square inch discharge area for one square foot of grate surface of boiler; one "Metropolitan" or equally good feed water injector; one steam gauge not under eight inches diameter; one water column with glass gauge and quick shut-off device to permit renewal of glass under pressure, and 3 try cocks with lifting handles to be operated from fire room floor, all to be connected up with blow-off pipe for bottom of water column and glass gauge, piping to be carried down in front and terminated with valve at height of hand; an extra heavy standard brass swing check valve for direct feed water pipe into boiler; three extra heavy standard brass feed water globe valves, one for direct line into boiler, one for injector branch, and one for pump branch.

18. All valves, gauges, and other fittings, as herein specified and not of the boilermaker's own manufacture, must be designated in the bid, with the maker's name and class of manufacture.

19. Bidders are required to furnish with their bids full specifications of the boiler, and a drawing of the foundation and setting of a single boiler, and a detailed estimate of all material, in addition to that furnished under the specifications, which will be required to set up the boiler complete ready for steaming.

20. The successful bidder will be required to furnish, without extra compensation and for a reasonable time, the services of a competent engineer to superintend the erection of the boiler, the Government to furnish the ordinary labor required.

21. Where not otherwise specifically provided above, the material and workmanship shall conform to the regulations of the Board of Supervising Inspectors of Steam Vessels in respect of boiler construction, and to the rules adopted by the American Boiler Manufacturers' Association.

GENERATING SETS.

22. The set shall consist of an engine and generator, secured on a common bedplate, with solid shaft, or connected by a solid flanged approved coupling, through bolted and keyed, as may be required.

23. Separate bids upon the engine, including bedplate, extension shaft, and outboard bearings, and upon the dynamo, will be considered, but, other things being equal, preference will be given to bids upon generating sets as a whole.

24. All parts must be accessible for examination, adjustment, and repair.

25. Suitable arrangements must be provided for effectively lubricating all parts of the set which require lubrication, and for collecting and recovering all surplus oil. Oil guards shall be fitted where necessary to prevent oil from being thrown. The set must operate without noise, be thoroughly balanced, run true, and must be capable of running for long periods under full load without undue heating or wear. All nuts likely to work loose to be lock nuts; all lock nuts to have a suitable locking device. All parts must be of standard sizes, so as to be readily duplicated.

26. Engine and dynamo must be thoroughly well built and of the best material and workmanship throughout, the material entering into each part being of the kind and grade especially manufactured for and best adapted to the construction of such part. Both must be of standard makes, well tested by actual use.

27. Complete working drawings of generating set must be furnished with the set.

28. The dynamo, when completed, shall be subject to test at the factory in presence of an agent of the United States, and the conditions as to output, regulation, temperature, and efficiency will be rigidly enforced.

29. The efficiency of the set must be as follows: The electrical power, as measured by standard ammeter and voltmeter at terminals, shall be 80 per cent of the power developed by the engine, as measured by an indicator. This same test shall be applied again after the set is installed in the battery. The heating test shall be made by the resistance method.

THE ENGINES.

30. The engines are to be of the horizontal center-crank, high-speed type, equal to the best and most approved automatic engines in the market. They must be strongly built of the very best materials, thoroughly balanced, and of high efficiency and economy.

31. The engines must be designed to work most economically with a steam pressure at the engine of 100 pounds per square inch. They must be able, at that pressure, to drive without strain the dynamos specified below continuously at full load and for three hours at 15 per cent overload. The minimum I. H. P. at the above pressure and at the speed required by the dynamo shall be not less than K. W. plus one-third K. W., plus 10 per cent.

32. All parts subject to wear, especially those which may affect the alignment of the engine, must be accessible and susceptible of easy adjustment and repair.

33. They must be able to bear, without injury, the throwing on or off of the entire load by quickly making or breaking the electrical circuits.

34. The cylinders will be made of the best grade of hard, close-grained charcoal iron, accurately bored and finished to micrometer measurements; the crossheads, connecting rod, shaft, piston, and valve rods, and all nuts, bolts, etc., to be of the best forged steel. The thickness of metal in cylinder walls will be heavy to allow for reboring.

35. The engine frame will be carefully designed for strength, compactness, and rigidity. The subbase will be of cast iron, of strong and substantial form and attractive design.

36. Cylinders shall be fitted with relief valves arranged to work automatically in addition to the usual drain cocks.

37. The cylinders must be fitted with indicator motions and connections, and the best obtainable and approved sight-feed cylinder lubricators. Sight-feed oilers or self-oilers connecting with all moving parts shall be used. Compression grease cups may be used on governor and valve mechanism. The cylinders and valve chests must be covered with a suitable nonconducting material and encased in a fireproof covering.

38. The engines will be fitted with automatic governors which shall be simple in construction, and be made of the most durable material. The governor with open throttle must so regulate the speed of the engine that when 100 per cent of its rated capacity is instantly thrown upon the engine or thrown off, the momentary change in speed shall not be more than 2 per cent of the constant speed.

39. Before shipment the engines will be set up in the shop and carefully gone over to determine correct alignment, thorough balance of all parts, proper fitting of bearing surfaces, tightness of steam joints, valves, and pistons, and general running qualities. Due notice of time of test will be given the purchasing officer in order that he may be represented at the test if he so desires. If no representative is present, a certified copy of the test will be promptly furnished, and if there should be doubt as to the engine fulfilling the specifications in any particular, such additional tests as may be deemed necessary by the purchasing officer to settle any doubtful point will be made by the contractor without expense to the United States.

40. The proposal for engine shall include the subbase extensions, outboard bearings, and dynamo shaft, designed, drilled, and planed to conform to the drawings and gauges to be furnished by the dynamo builder.

41. The valves shall be of a simple type, perfectly balanced, and of a design which will insure steam-tight joints and long service. The design must permit correct and speedy renewals to be made at small cost. They will be accurately adjusted in the shop by means of a steam indicator.

42. With each engine will be furnished throttle valve, foundation bolts, nuts, and plates, automatic cylinder relief device, cylinder and other lubricators, exhaust flange or Y, cylinder drip valves, hand oil pump, indicator reducing motions including 3-way cock and piping, indicator plugs, and complete set of drop-forged case-hardened wrenches, special wrenches and spanners suitably mounted on a hardwood frame.

43. Bidders are requested to furnish with their proposal a set of catalogue illustrations, or working drawings, and a complete description of the engine they propose to supply, including a statement of the diameter of cylinder, length of stroke, revolutions per minute, guaranteed I. H. P., guaranteed weight of dry steam per brake H. P., length, width, and height over all, diameter of steam and exhaust pipe, and shipping weight. The information will also include a friction and efficiency guarantee, and these will be expressed in the I. H. P., used by the engine to maintain normal speed without any other load. Failure to provide this information will prevent consideration of the bid.

44. The dynamo, if purchased separately, will be attached to the engine at the place of delivery by the United States.

45. The purpose of these specifications is to obtain high-grade engines of established reputation for strength, endurance, economy of operation, smoothness of running, and accuracy of speed regulation. Bidders offering engines not known to the purchasing officer as belonging to the above class must file evidence of their equality with standard makes to insure consideration of bid.

46. The contractor will supply free of charge any part that may fail on account of defective design, workmanship, or materials within one year after shipment.

(These specifications can be readily adapted to a compound noncondensing plant by appropriate change of words in section 30, and by substituting 125 pounds pressure per square inch instead of 100 pounds in section 31. A corresponding change in section 30 and the substitution in section 31 of 150 pounds instead of 100 pounds per square inch will adapt them to a compound condensing plant.

If the vertical type is called for, a clause should be added to section 35 stipulating that the engine frames should be of a design and construction to insure freedom from vibration of the cylinder, to which engines of that type are liable.

If belt connection be desired, the paragraphs under "Generating sets" may be omitted, the wording of section 40 above may be replaced by a statement of the width and speed of belt, and the same data added to the dynamo specifications.)

APPENDIX.

METHOD OF DETERMINING RATIOS BETWEEN K. W., I. H. P., AND B. H. P.

1. Relation between I. H. P. is expressed by the formula—

$$\text{I. H. P.} = \frac{\text{K. W.} \times \text{per cent overload} \times \text{ratio of one K. W. to one I. H. P.}}{\text{Efficiency of generating set.}}$$

Assuming efficiency of set at 80 per cent and overload at 15 per cent, the formula becomes for a 50 K. W. set—

$$\text{I. H. P.} = \frac{50 \times 1.15 \times 1\frac{1}{3}}{.80} = 95.84$$

2. Ratio between I. H. P. and B. H. P. may be found as follows, boiler pressure being taken at 100 pounds gauge pressure:

Assuming feed water at 68° F. and disregarding feed-water heater, one pound of steam at 100 pounds gauge pressure represents 1,148.9 British thermal units.

The consumption of steam in a simple engine, including one pound for pumps, condensation in pipes, etc., may safely be taken at 37 pounds per I. H. P. per hour. Multiplying 37 by 1,148.9 gives 42,509 B. T. U. per I. H. P. of simple engine. The number of B. T. units in a boiler H. P. is 33,305. Dividing 42,509 by 33,305, we obtain 1.276, the latter being the factor by which the I. H. P. must be multiplied to obtain the rated B. H. P. Multiplying the I. H. P. in the case supposed (95.84) by 1.276 we obtain 122.3 as the B. H. P. for a 50 K. W. In other words, 2.44 B. H. P. are required for each K. W. of generator.

3. In the specifications, B. H. P. is expressed in evaporative units, the number of such units being 84 for each K. W. This number is determined as follows:

33,305 B. T. U. represents one boiler H. P. 965.8 B. T. U. represents the evaporative unit or heat required to generate one pound of steam from and at 212° Fahr. Dividing former by latter gives 34.48 evaporated units for each B. H. P. Multiplying by the ratio 2.44, we have 84 as evaporative units required per K. W. of generating set.

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from Office of Chief of Engineers

PROFESSIONAL PAPERS, CORPS OF ENGINEERS, No. 27.

(2)

REPORT

OF

BOARD OF ENGINEERS

ON

SPECIFICATIONS

FOR

ELECTRIC LIGHT AND POWER INSTALLATIONS

OF

SEACOAST BATTERIES.

WASHINGTON;
GOVERNMENT PRINTING OFFICE.
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WAR DEPARTMENT,

Document No. 125.

Office of the Chief of Engineers.

UNITED STATES ENGINEER OFFICE,
New London, Conn., July 25, 1900.

GENERAL: I have the honor to transmit herewith the report of the Board of Engineer Officers, convened by Special Orders, No. 19, Headquarters Corps of Engineers, May 11, 1900, accompanied by three sheets of drawings appertaining thereto.

Very respectfully, your obedient servant,

SMITH S. LEACH,
Major, Corps of Engineers,
Senior Member.

Brig. Gen. JOHN M. WILSON,
Chief of Engineers, U. S. Army.

OFFICE CHIEF OF ENGINEERS, U. S. ARMY,
August 10, 1900.

Respectfully submitted to the Secretary of War.

The accompanying report of the Board of Engineer Officers, constituted by Special Orders, No. 19, Headquarters Corps of Engineers, 1900, contains recommendations touching the character of the electric light and power plant best adapted to the requirements of seacoast forts, and is accompanied by specifications governing the installations of such plants.

During the past four years a number of electric plants have been installed and used in fortifications, and the experience thus gained has been of great value. The object of the present recommendations and specifications is to profit by the lessons of experience and to insure uniform practice for future work.

It is recommended that the report of the Board be approved, and that, on account of its interest to engineer and artillery officers, 500 copies be printed at the Government Printing Office and furnished for the use of this office on the usual requisition.

JOHN M. WILSON,
Brig. Gen., Chief of Engineers,
U. S. Army.

WAR DEPARTMENT, *August 15, 1900.*

Approved as recommended by the Chief of Engineers.

ELIHU ROOT,
Secretary of War.

REPORT.

UNITED STATES ENGINEER OFFICE,
New London, Conn., July 2, 1900.

The Board of Engineer Officers, constituted by Special Orders, No. 19, Headquarters Corps of Engineers, May 11, 1900, has the honor to submit the following report:

The Board met at the Engineer Department in Washington on May 21, 1900, at the call of the senior member, all the members being present. The Board remained in daily session until May 25. The papers referred were considered, as well as others informally presented to the Board. These were supplemented by a statement from Captain Kuhn reviewing the action and attitude of the Engineer Department on the question of electrical installations to date. By May 25 the Board had traversed the subject on broad lines and had arrived at general conclusions on the leading and fundamental points. Adjournment was then taken, with the sanction of the Chief of Engineers, to permit subcommittees of the Board to take up the details of subjects allotted to them, with the understanding that the Board would be reconvened at a later date to complete its work. Under Special Orders, No. 28, Headquarters Corps of Engineers, June 20, 1900, reconvening the Board, a session was held at New London, Conn., beginning June 27 and continuing until June 30, 1900. The results presented by the subcommittees of the Board were canvassed and incorporated into a final report, after the adoption of which the Board adjourned sine die.

It is the opinion of the Board that the lighting and power plants should have as complete protection against all kinds of fire as the passages and minor rooms of emplacements. Consistent with this principle, the power rooms should be so designed as to secure the best possible light and ventilation. It may be conceded that rooms so protected will, in many cases, be somewhat lacking in light, ventilation, and dryness as compared with commercial plants. But it is also true that no other part of an emplacement is as well adapted to the purposes of its occupancy as would be the case if protection from fire were not essential. Light and ventilation can be artificially supplied, and this should always be done. Dryness should be promoted as far as can be done by damp-proofing methods. The installation should also be designed with special reference to minimizing the effects of moisture. The Board has given the most careful attention to this

condition. Whatever is still required after the above conditions have been realized must be supplied by the intelligent and unremitting attention of the garrison.

The power rooms should be of ample size and height, with arched ceilings when practicable. For a steam plant there should be separate rooms for boilers, for engines and generators, and for accumulators. For oil engines, separate rooms for engine and dynamo, for cooling tanks, if required, and for accumulators.

Centralization is considered desirable, but when resorted to should not be carried beyond the generating plant. The reserves, accumulator or other, should be distributed to the several batteries. As to distance, centralization is not recommended beyond the limits within which the standard voltages of all parts of the system can be maintained with reasonable expenditure for copper.

In discussing mechanical and electrical details for an installation the Board has been guided by the following considerations, stated in the order of their importance:

1. The greatest probability that the plant will be ready for service at any future time, having in view simplicity of design and freedom from deterioration.
2. Uniformity of methods of operation, and of methods of construction, so far as the latter involve the former.
3. Economy of operation.
4. Economy of first cost.
5. High commercial efficiency.

The Board is of the opinion that steam should be adopted as the standard prime mover, no other to be permitted, save in exceptional cases where water for steam can not be had.

BOILERS.

The ordinary upright boiler is considered best adapted to use in these installations. It is compact and simple in construction and operation. Being internally fired, the shell can be made with a large factor of safety, limiting explosions to those of minor character. Its vertical position produces a symmetry of heat distribution not attained in any other type of boiler, and greatly contributes to its life by minimizing the strains of rapid heating and cooling. It reconciles as well as can be done the antagonistic attributes of quick steaming and steady water level, while there is less risk, than in horizontal types, of injury or accident from low water. Verticality of the principal heating surfaces reduces to a minimum the rate of corrosion when not in use. Good upright boilers are made in nearly every section of the country, and they are nearly enough alike to fall within the standard of uniformity which the Board regards as necessary. The boiler should be

designed for a working pressure of 100 pounds; should not fall below the standard specifications for boilers for land service in any respect, and should be completely equipped with fittings and tools. The rated capacity should be at least 25 per cent in excess of the maximum requirements of the engine. Where sufficient headroom can not be provided for one boiler of the required capacity, a battery of the same type should be used, steam but not water connected. The feed should be in duplicate, both appliances completely installed independently of each other. The boiler should be covered with mineral nonconducting material, but its application should be deferred, if practicable, until steam has been carried for sufficient time to make sure that the shell is tight. If the feed water is not supplied under pressure, a tank should be used to store water for filling the boiler by gravity. A tank will also be required when the supply is meager, to utilize the flow when the plant is not running. The best tanks are of cast iron, of sectional construction.

The usual feed will be by injectors, and no heaters will be required. When the use of boiler compound is desirable, one of the feeds should be a pump, and its suction should be provided with a branch to take the compound. The occasional and careful use of cold feed will not injure the boiler.

Cases where purification of feed water is necessary must be treated individually. In such cases the purifier, of whatever kind, should deliver the treated water to the regular feed; or, in other words, should be added to and not combined with the standard plant. A branch suction should be carried directly to the supply, so that in emergencies the boiler may be fed with untreated water should the purifier fail.

In the case of rooms having vertical cover, the escape of gases from steam boilers and oil engines should be through a cast-iron or vitrified pipe or stack centrally supported in a ventilating shaft, and provided with a hood to protect the pipe and the annular opening.

GENERATING SET.

The generating set which the Board considers best adapted to the purposes in view consists of a vertical, high-speed, automatic engine, direct connected to a direct-current, compound-wound, multipolar dynamo, the engine and dynamo resting on a common bed plate. A single-cylinder engine is preferred, so long as there is headroom for one of the required power; otherwise, a double-cylinder engine must be used. Ample provision should be made by relief valves against injury to the engine from wet steam or priming of the boilers; and this done, a separator or steam trap will not be required and should not be used.

Automatic lubrication should be carried as far as possible, and all

appliances for this purpose should be chosen for simplicity and certainty. The use of surplus oil with a view to recovery, filtration, and re-use is not recommended.

The disposition of the exhaust is a matter of importance. In all cases an exhaust lead should be provided to a point whence escaping steam will not be visible from the front of the battery, and will not penetrate to any part of the emplacements. Wherever water under pressure is available, the addition of an injection condenser to kill the exhaust is recommended. This will take care of the steam and remove back pressure without materially reducing the temperature of the exhaust end of the cylinder. A higher vacuum is not recommended.

RESERVES.

Reserves should be in the form of accumulators, except for emplacements for guns of calibers less than 6-inch, and their capacities should be determined by the lighting load only, without reference to the power load represented by motor-driven machinery, as the hand-operating devices of lifts and carriages form a satisfactory reserve. So long as the present types of emplacements are adhered to, the reserves for the lower calibers should be portable, except where several emplacements of this character present a center of distribution at a distance from the generating plant, for which a single accumulator reserve unit may be desirable. Portable illuminating devices are on the market, from which a satisfactory reserve can be selected to meet individual conditions.

The reserves should be so arranged and distributed that a single accident or injury can not disable, simultaneously, both generator and reserve, and also so that an injury to any outside wiring such as leads to the central generating plant can not disable the reserves. These conditions require that the reserves shall be separate for each battery or distributing center, and installed in a protected room in the battery to which they belong, with a separate switchboard panel. This arrangement will have the incidental advantage of short leads from the accumulator to the lights, thus reducing the number of cells required for a given voltage, and will permit each reserve to be adapted to its particular load, giving better conditions of service than a varying load on a larger unit.

The accumulators should be so arranged that they can be divided into two equal parts which can be charged in parallel and discharged in series, the voltage during both charge and discharge being regulated by means of rheostats. This arrangement has many advantages for the fortification service. No change is required in normal voltage at the bus bars; therefore the lights and motors can be operated while the accumulator is being charged, and in a central plant all the accu-

mulators can be charged at their normal rates irrespective of their condition as to charge, and this without interfering with the operation of any of the lights or motors throughout the installation. The generator can be of a standard commercial type, as special winding for raising the voltage during the charging of the accumulators is not required. The danger of discharging the accumulator through the generator is reduced to a minimum since the counter electromotive force due to the accumulator in parallel is much below the normal voltage of the generator. The wiring and switchboard arrangements and the manipulation of the accumulators are made exceedingly simple. The greatest disadvantage of this method of charging is its low efficiency; but this, while a serious objection in commercial practice, is of secondary importance in fortification work.

The capacity of the accumulator should be sufficient to carry the full lighting load for a period, depending on local conditions, of from four to eight hours without reducing the voltage of the battery below 1.9 per cell, measured while discharging at normal rate, and this voltage should be considered a minimum below which the battery should never be discharged except in an emergency. The number of cells for the accumulator in any given case is determined by the voltage of the lighting circuit, and in the general case where 110-volt lamps are used, 58 cells in series will be sufficient.

Connections between elements should be so designed that no metals other than lead shall be exposed to the fumes from the accumulator.

The insulation of the cells from the earth should be as perfect as possible, and of the latest and most approved method; and the installation and initial charging should be in strict accordance with the instructions and specifications of the makers.

Glass jars have distinct advantages as containers for the electrolyte, but the larger commercial sizes should not be used when exposed to concussion. When they are used it has been found desirable to place cushions, such as hard rubber, on the edges of the jars beneath the supporting lugs of the plates of the element to distribute the weight and prevent strains due to changes in temperature, as these strains make the jars sensitive to shock.

Type specifications for an accumulator are appended hereto, covering the important requirements for fortification service, and it is believed that several of the standard commercial types of accumulators will comply with them.

SWITCHBOARDS.

While uniformity in all parts of the installation is exceedingly desirable, the Board is of the opinion that identical arrangement and operation of all switchboards is so much so that it should be insisted upon in future constructions. The chief requirements are, a dry and

clean situation, high insulation, complete protective appliances, and the reduction of the number of manipulations required to the lowest possible limit. The Board presents and recommends for adoption standard panels for generators and accumulators, drawings and specifications of which are appended hereto.

For each installation there will be required one generator panel and as many accumulator panels as there are reserves. The generator panel will be installed in the power room and the accumulator panels with the reserves. When a reserve is in the same battery with the generating plant the accumulator panel will be installed as a part of the power room board, but when in a different battery provision should be made for the installation of this panel in a position secure from fire, convenient of access from the main entrance, removed from lines of ammunition service, and as near the accumulator room as possible. For future constructions, it is believed that an anteroom placed next the accumulator room will be convenient.

Generator panel.—In addition to the usual measuring and indicating instruments, feeder switches, etc., the generator panel has been provided with cut-outs and fuses to protect the generator from overloads. The cut-outs are designed to open with 25 per cent overload, and the fuses to blow with 50 per cent overload.

The magnetic overload protection is in two separate instruments, not to be operated simultaneously, so that one is free to act during the closing of the circuit should a short circuit exist. One of these cut-outs is provided with an underload attachment, to protect the dynamo from discharge of the accumulators.

Accumulator panel.—The accumulator panel has been so arranged that a triple-pole double-throw switch makes all the connections for charging or discharging the battery, as is desired, and on discharge also protects the generator of the central plant from short circuit by breaking one pole of its leads.

The voltage on both charge and discharge is regulated by means of the main rheostat, two small equalizing rheostats being used to correct any inequalities in the halves of the battery on charge, and also serving for fine adjustments of voltage on discharge, as they are then in series with the main rheostat. Both ammeters are double reading, and on charge each records the current in one-half of the battery. On discharge they are in series, and both record the rate of discharge. This feature is valuable, as it gives a test for variation in calibration of the instruments and secures uniformity in both the instruments and their service.

The pilot lamps have been connected across the bus bars, and will not light up when the triple-pole switch is in the position "Charge," unless the generator is in operation and ready for charging the accumulator.

WIRING METHODS.

The electric light and power installations throughout will be for direct current on the two-wire system. Lamps and motors will be designed to operate at 110 volts, and the maximum drop in the installation for any single battery should be limited to 2 volts if practicable, thus giving a normal voltage of 112 at the bus bars of the accumulator panel from which the lights and motors are supplied. In a central plant the voltage of the generator should be limited to 115 volts, if practicable, to minimize the fluctuations of voltage at the accumulator bus bars due to variations in loads, and the conductors from the central plant to the several batteries should be so proportioned as to give the same drop from the generator to each of the accumulator panels when carrying the normal loads.

Exterior wiring.—Apart from exposure to fire, all the conditions likely to arise in the exterior wiring can be met by air lines of weatherproof wire, with high-grade insulators, on stout poles of moderate height. Such lines should, in the opinion of the Board, be used whenever they can be concealed from the enemy's view. So concealed, the chances of a hit are negligible. All overhead lines must be provided with lightning arresters whenever necessary for the protection of the generator and reserves.

When an air line can not be concealed from view, the cables should be placed underground. They are then invisible, and the probability of a hit is no greater than for a concealed air line, except near the batteries, where fire is likely to be concentrated. Across such ground the feeders should be carried in well-laid vitrified conduit, at a depth sufficient to give ample cover. The conduit leading from each emplacement or other structure should terminate in a manhole beyond limits of probable danger and at a level well below frost. To complete the line between any two points the corresponding manholes should be connected by a cable laid in the ground below the reach of frost. In laying such cables the earth in contact with the cable must be freed from hard substances by screening, if necessary. If the distance between termini be short the two manholes become one, or may be omitted, and the entire line will be in conduit.

Manholes should be of ample size, elongated near the bottom in the direction of the conduit. They should be constructed to exclude surface water, should be carried below conduit level sufficiently to form sumps or catch-basins, and should have their sides water-tight and their bottoms open, or connected with a drain, according to the nature of the soil.

Conduit should be laid in accurate alignment, with precautions against future disturbance, and joints should be made as tight as possible to preclude the entrance of foreign substances; but water-

tightness is not essential. Conduit should be given an inclination sufficient to promote rapid drainage, and every part of the exterior wiring should be so designed and constructed as to receive no injury from the occasional presence of water.

All underground cables should have, as minimum requirements, conductors of soft annealed copper, 98 per cent pure, stranded if larger than 50,000 circular mils, heavily and evenly tinned, and covered by an approved insulation five-thirty-seconds of an inch thick, protected by a lead sheathing one-eighth of an inch thick, with a saturated fibrous covering over the lead. Joints should follow the same construction, with perfect continuity of each of the parts.

Interior wiring.—In designing the circuits, those for motors should be kept entirely separate and distinct from those for lights. It may be found desirable to separate the lighting circuits at the switchboard into two divisions, one for magazines and their rooms and passages wholly dependent upon artificial light and one for rooms and passages requiring light at night only. The same result may be obtained on a single circuit by introducing switches for the latter class of rooms. The wiring should be so proportioned as to give a drop not exceeding two volts to the farthest lamp, and no wire should have a normal current density exceeding 1 ampere per 1,000 cm. No wire of smaller size than No. 14 A. W. G. gauge should be used, and all conductors larger than No. 10 should be stranded.

All branch circuits should be fused; those of less than twenty lamps at 100 per cent overload, others at 50 per cent, except that no fuse less than 3 amperes capacity is to be used.

Switches above 10 amperes capacity should be of the double-pole knife pattern. For 10 amperes and below they may be of any reliable turn-handle or push-button snap pattern that may be water-tight.

Conduit.—The entire system of conductors should be inclosed in conduit so constructed as to be moisture proof and practically air-tight. This conduit installation may be either exposed or concealed. If exposed, the lines should be carried along ceilings or walls, supported at proper intervals and at not less than 1 inch from the concrete. If the installation be concealed, the system should be laid in the concrete of the ceilings and intervening walls, about 2 inches above the ceiling level, determined by the dimensions of the outlet boxes. In both systems noncorrosive materials should be used throughout except for the conduit proper, which may be of steel when the conditions permit its protection from corrosion by enamel or paint.

The best method of making lamp and fuse boxes moisture proof and air-tight is to replace the usual metal covers by a heavy globe of clear flint glass screwing against a gasket. Metallic guards are not considered necessary for the protection of lamps where outer globes are used. A drawing is presented with this report which illustrates this type of construction which has been found satisfactory in service.

LAMPS.

The number of lamps required for any room will depend upon the size and height of the room, the use for which it is intended, the color of the walls, and the luminous intensity of the lamps.

The walls of all rooms, magazines, and interior passages should be whitened. With whitened walls it is estimated that for rooms and passages whose ceilings do not exceed 10 feet in height the number of lamps will average one 16-candlepower lamp for each 100 square feet of floor surface, the lamps being so distributed as to give greater or less illumination, as the different parts of the battery may require.

Care should be taken to secure lamps which will give a suitable distribution of light, as many commercial forms of incandescent lamps are deficient in intensity in the direction of their axes. Specifications for lamps are hereto appended.

MOTORS.

Motors should be of the completely inclosed type and their general features adapted to the character of the installation already recommended for adoption. The requirements considered essential are embodied in the appended specifications. Except as to current, voltage, and inclosure, these specifications do not apply to small fan motors. When such are used the best commercial types will be satisfactory.

Specifications for wire are also appended.

On account of the widely varying conditions at different localities, the Board can not propose a complete set of specifications for all electrical installations. In all such specifications there must appear requirements and restrictions which are purely administrative in their character, with which the Board has nothing to do, and which the contracting officer can best prescribe. The specifications herewith submitted are intended to cover, from designing and constructive standpoints, the essential features of a standard installation which are believed to be adaptable to all conditions likely to arise. These features should be incorporated in every set of specifications, and, in the opinion of the Board, it will conduce to the objects in view if the language suggested be uniformly adhered to.

Respectfully submitted.

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APPENDIX.

SPECIFICATIONS.

SPECIFICATIONS FOR BOILER AND ACCESSORIES.

1. The boiler shall be of —— horsepower, of the upright, fire tubular type, with dry head.

2. The extreme length of the shell shall be not less than one and five-eighths nor more than two and one-eighth times its greatest internal diameter. There shall be not less than 15 square feet of heating surface and 0.5 square foot of grate surface for each horsepower of the rating.

3. All parts of the boiler subject to steam pressure and not specifically excepted hereinafter shall be of mild, nontempering, open-hearth steel of 55,000 to 60,000 pounds tensile strength, with not less than 56 per cent of ductility as determined from contraction of area at point of fracture under test, and by an elongation of 25 per cent in a length of 8 inches. The steel shall be from mills of established reputation for boiler materials, the metal entering into each part of the boiler being of a grade especially manufactured for and best adapted to use in such part. All plates, both of shell and heads, must be plainly stamped with the name of the maker, the brand and the tensile strength, the brands so located that they may be seen on each plate after the boiler is finished. Each shell plate must bear a coupon, which shall be sheared off, finished up, and tested by the maker of the boiler. Each coupon must fulfill the above requirements as to strength and ductility, and must also stand bending down when cold, when red hot, and after heating to redness and quenching in cold water, without signs of fracture. The builder of the boiler must furnish a sworn transcript of the record of these tests, showing affirmatively that each and every one of them has been made, and the result.

4. The thickness of the shell shall be not less than one-sixty-fourth of its internal radius, with a minimum limit of one-fourth inch. The fire box shall be of the same thickness as the shell, and the tube sheets one-eighth inch thicker.

5. The fire-door ring may be double flanged and riveted to the shell and fire box, or the fire box may be flanged out to meet the shell, the

former construction preferred. The water-leg ring may be of the same construction, or may be forged up from bar steel with rivets driven from the outside. Cast iron bottom and fire-door rings are excluded.

6. All straight edges shall be planed and all circular edges turned smoothly and to the proper bevel. Irregular or double-curved edges must be neatly chipped to bevel before assembling.

7. The tube sheets must be flanged in presses, but may, if necessary, be trued up and finished with wooden mauls. Press work is preferred for all other flanging, but hand work will be admitted if done exclusively with wooden mauls.

8. Rivets will be sized and spaced in accordance with the requirements of the Board of Supervising Inspectors of Steam Vessels for steel plates and steel rivets. The longitudinal shell seams shall be double riveted. Rivet holes may be drilled, or may be punched one-eighth inch below size and reamed. Reaming must be done in place, the sheets and heads being assembled with bolts and all holes brought fair. After drilling or reaming, the burr must be carefully removed. All holes must be brought fair by reaming before the rivet is inserted, and a driftpin must not be used. All rivets which can be reached by a machine must be power driven, hydraulic preferred.

9. Fire boxes shall be stayed to the shell with steel screw stay bolts pitched one inch for each sixteenth inch thickness of shell plates, the pitch to be measured on the inside of the fire-box sheet. The sectional area of stays in square inches, measured inside the bottom of the thread, shall not be less than one-sixtieth of the square of the pitch. The stays shall have 12 threads per inch, and shall be headed down cold at both ends.

10. All seams shall be caulked with a round-pointed tool, the shell seams outside and in.

11. The tubes shall be cold-drawn seamless steel or best charcoal iron lap-welded, 2-inch diameter, No. 12 U. S. standard gauge, except one on the outside, which shall be three-sixteenths inch thick. The tube sheets shall be drilled for tubes, and the edges of the holes shall be smoothly chamfered after drilling. There shall be one central tube, and the rest shall be in concentric circles with radii increasing by equal steps of $2\frac{3}{4}$ inches in each circle. The tubes shall be $2\frac{3}{4}$ inches apart, center to center, measured on chords of the circle, and shall be grouped in three nests, each occupying a sector of 120°. The holes in the lower or crown sheet shall be drilled to a close fit, requiring light driving to enter the average tube. The holes in the upper sheet shall be drilled large enough to permit the tubes to be entered and withdrawn freely, and a liner of hoop iron shall be used to fill the space between tube and head, so that the upper end will require no more expansion than the lower end. After expanding, the lower ends of the

tubes shall be slightly flared and the upper ends smoothly beaded. A fusible plug of size and pattern approved by the United States Board of Supervising Inspectors shall be placed in the heavy tube one inch below the lower gauge cock and accessible through a hand-hole.

12. The fire door shall be of steel plate, fitting the opening closely, with perforated lining and substantial hinges and latch. Three equally spaced hand-holes shall be cut near the bottom of the water leg, and the same number at the level of the crown sheet opposite the spaces between nests of tubes. Hand-hole plates shall be of cast iron, close fitting, with ample surface to receive packing, with steel bolt and steel or cast iron yoke.

13. There shall be a substantial cast iron base, forming foundation, ash pit, and grate bearers. The ash-pit doors must be close fitting, and it is preferred to have them slide. The hood or smoke box shall be of fine-grained cast iron, hemispherical or conical, with doors near the bottom to give access to the upper tube sheet. The upper edge shall take the form of a cylindrical collar, 3 inches high, — inches outside diameter.

14. (Here shall be inserted specifications for connections to the smokestack or chimney.)

15. The boiler shall be supplied with the following fittings, all provided with attachment to boiler, arranged for —— inches of nonconducting covering, viz:

16. A muffled pop safety valve, with nickel seat and all parts except the spring of brass or composition, having 1 square inch of opening for not less than 3 nor more than 4 square feet of grade surface; safety valve to have a handle for lifting the valve from its seat, and to be connected with the boiler by a separate pipe of an area throughout not less than the valve area. No valve shall be placed between the safety valve and the boiler.

17. A 6-inch brass-cased, noncorrosive steam gauge, of a make approved by the United States inspectors, with a siphon made up from pipe and fittings, with an air cock at the lowest point and a stop-cock just below the gauge.

18. Three brass gauge cocks, with copper drip pan and pipe reaching below the shell of boiler.

19. A glass gauge, of full range of gauge cocks, with brass valves, fittings, and guards, and —— extra glasses.

20. A brass straightway blow-off valve, with screw motion.

21. Two single-motion, self-contained injectors, each having a capacity to supply the boiler, and independently connected throughout with all usual globe and check valves; the feed in all cases to enter the boiler above the crown sheet and near enough to a hand-hole to permit a deflecting elbow to be placed on the inner end.

(21. Alternative. One single-motion, self-contained injector, having

a capacity to supply the boiler; and one double-acting, horizontal steam pump of capacity to supply the boiler at normal speed. Both injector and pump to be independently connected from the supply to the boiler, and the pump to have a branch in the suction to take boiler compound. The feed in all cases to enter the boiler above the crown sheet and near enough to a hand-hole to permit a deflecting elbow to be placed on the inner end.)

22. The boiler shall be provided with connection for —— -inch steam pipe, the connection to consist of a cast-iron flanged nozzle or screwed flange riveted to the shell of the boiler near the top. If a nozzle be used its upper flange must be accurately squared.

23. The main steam pipe shall be of the same size as the engine inlet, if the lead be less than 20 feet, or one size larger than the engine inlet if the lead be longer. It shall have a shut-off valve as near the boiler as possible.

24. All pipes carrying live steam shall be covered with insulation in sectional form, and the boiler shall be covered with approved plastic composition of the same thickness as that on the pipes.

25. The valves shall be of brass or composition, and those not otherwise specified shall be globe valves. The latter shall be of standard make, and, other things equal, those with renewable seats will be preferred.

SPECIFICATIONS FOR GENERATING SET.

26. The set shall consist of an engine and generator, secured on a common bed-plate and connected by a solid flanged approved coupling, through bolted and keyed.

27. All parts must be accessible for examination, adjustment, and repair.

28. Suitable arrangements must be provided for effectively lubricating all parts of the set which require lubrication, and for collecting and recovering all surplus oil. Oil guards shall be fitted where necessary to prevent oil from being thrown. The set must operate without noise, be thoroughly balanced, run true, and must be capable of running for long periods under full load without undue heating or wear. All nuts likely to work loose to be lock nuts; all lock nuts to have a suitable locking device. All parts must be of standard sizes, so as to be readily duplicated.

29. Engine and dynamo must be thoroughly well built and of the best material and workmanship throughout, the material entering into each part being of the kind and grade especially manufactured for and best adapted to the construction of such part. Both must be of standard makes, well tested by actual use.

30. Complete working drawings of generating set must be furnished with the set.

31. The dynamo, when completed, shall be subject to test at the factory in presence of an agent of the United States, and the conditions as to output, regulation, temperature, and efficiency will be rigidly enforced.

32. The efficiency of the set must be as follows: The electrical power, as measured by standard ammeter and voltmeter at terminals, shall be 80 per cent of the power developed by the engine, as measured by an indicator. This same test shall be applied again after the set is installed in the battery. The heating test shall be made by the resistance method.

33. *The engine.*—To be vertical, single or double cylinder, self-contained, strongly built, thoroughly balanced, and of high efficiency and economy. It shall be designed to work most economically at 100 pounds pressure. It must be able at that pressure to drive, without strain, the dynamo specified below continuously at full load and for three hours at 15 per cent overload.

34. All parts subject to wear must be accessible for adjustment and repair, and especially those which may affect the alignment of the engine. It must be able to bear, without injury, the throwing on or off of the entire load by quickly making or breaking the electrical circuit.

35. The cylinder must be fitted with relief valves arranged to work automatically and guaranteed to protect the engine against injury from wet steam or priming of the boiler, it being understood that no separator is to be used. In addition to these valves, the usual drain cocks are to be provided.

36. The engine must be fitted with an automatic governor, simple and of durable material. The governor must control the speed of the engine, the throttle being wide open, within the following limits: The variation in speed must not exceed 2 per cent between limits of no load and full load at the rated pressure.

37. The cylinder and valve chest must be covered with a suitable nonconducting material and cased with an approved metal covering. The engine must be fitted with indicator motions and connections and an upflow sight-feed cylinder lubricator. Stationary sight-feed oilers, or self-oilers, connecting with all moving parts, must be used, except that compression grease cups may be used on the governor and valve mechanism.

38. *Generator.*—The generator shall be direct current, constant potential, compound wound, multipolar, delivering 115 volts at its rated speed. The compounding of the generator must be such that at the designed speed of the engine the voltage shall at no point of the characteristic curve vary more than 2 volts over the whole range from no load to full load, both up and down, no change being made in the field rheostat and the brushes being at the neutral point. The arma-

ture must be thoroughly ventilated, well balanced, and run true, and while firmly secured on its shaft must admit of being readily removed when necessary. The shaft must have a large bearing surface, with self-aligning and self-oiling bearings, and run cool.

39. The armature winding must be so arranged that the brushes in normal position shall be readily accessible.

40. The commutator segments must be numerous and of pure copper, well insulated with mica, of the proper hardness to wear at the same rate as the copper, and of ample depth for the capacity of the machine. There must be ample brush-working and radiating surface.

41. The rocker must have a fine adjustment. The brushes must be of carbon, and —— extra sets shall be furnished. The brush holders must be so mounted that they can be readily shifted simultaneously backward or forward. There must be no sparking at the brushes when properly set, between no load and 15 per cent overload. The brush holders must be provided with hold-off as well as feeding devices. Plurality of brushes on each range is desirable.

42. The whole of the circuits shall be of copper, of conductivity not less than 99 per cent of pure copper. The windings of both field and armature must be protected from mechanical injury and must be painted with a water-excluding material. All insulation must be of materials absolutely unaffected by moisture, and all paints and varnishes used in the assembling and finishing of the machine must be selected with especial reference to their moisture-proof qualities. The insulation resistance between circuits and between copper and iron parts must not be less than 1 megohm under the application of 1,000 volts pressure.

43. The generator must be capable of running at its full rated capacity at 115 volts for eight hours, or at 15 per cent overload for three hours, without an increase of temperature in any part, except commutator, of over 40° C. above surrounding air; and the commutator shall not increase in temperature more than 50° C. above surrounding air after running for eight hours continuously at the rated load. The heating of the coils shall be measured by the resistance method. The generator shall be designed to run at underloads with the maximum efficiency attainable in view of the full-load efficiency specified for the set.

SPECIFICATIONS FOR ACCUMULATORS.

44. The accumulator shall be some form of the Faure or Planté type of lead battery, or a combination of these types, having a normal discharge rate of —— amperes for eight hours, with a watt efficiency not less than 80 per cent. The active material of the elements must be supported by a grid of such form and in such manner as to hold it securely in position, even when subjected to considerable change of

volume due to improper use of the accumulator. The form of construction must be satisfactory to the engineer officer, and the elements must be so arranged as to be easily inspected and repaired.

45. With the accumulator there will be furnished all the materials and supplies, such as glass jars or lead tanks, electrolyte and carboys for same, sand trays, insulators, etc., necessary to complete installation; and also —— extra glass jars, — per cent more electrolyte than is required to set up the battery, — per cent more rubber separators than required to set up the battery,—— extra bolt connectors, ——lead terminal lugs,—— feet lead bus bar,—— pair rubber gloves, one voltmeter testing set, two hydrometers, and, if accumulator is to be installed in lead tank, two acid-proof inspection lamps.

SPECIFICATIONS FOR SWITCHBOARDS.

46. Switchboards shall consist of panels, upon which all instruments are mounted, and subbases, both bolted with bronze or copper bolts one-half inch in diameter, with nickel-plated heads and cushion washers, to a rectangular frame of steel angles reenforced at the corners with steel or wrought-iron angle braces, and provided with anchor bolts and wall braces for securing the board to the floor and supporting it at a distance of about 2 feet from the wall. The anchor bolts will be insulated from the frame by hard rubber bushings and washers, and the wall supports provided with insulating joints and turnbuckles for adjustment. The frames, wall braces, etc., will be thoroughly galvanized after manufacture and painted with two coats of black graphite paint.

47. The panel will be of the best quality Italian or Tennessee marble, or of the best slate, polished on face and edges, with one-quarter inch bevel on front edge of top and sides. If of slate, the panel must be thoroughly filled with paraffin or oil and polished by hand, without the use of enamel or paint.

48. The subbase will be of slate, polished as above on face and edges, with one-quarter inch bevel on top and sides. Both panel and subbase shall be free from flaws, cracks, metallic veins, or seams.

49. Except when expressly called for, no iron or steel shall be used in the construction or installation of the instruments, switches, or connections on any part of the switchboard, unless required for magnetic conditions; and when used they shall be thoroughly copper-plated and lacquered to prevent corrosion. All springs shall be of phosphor bronze or other suitable noncorrosive material.

50. A bronze name plate with black letters will be placed on the face of the board above each switch, to indicate its function or circuit, as shown.

51. Sketches showing the position of the instruments and the

arrangement of the connections on both generator and accumulator panels are inclosed herewith and form part of these specifications.

52. All the connections except fuses are to be firmly secured in place behind the board and must be of ample size to give a current density not exceeding 600 amperes per square inch for pure drawn copper, 400 amperes per square inch for cast copper, and 250 amperes per square inch for brass when carrying the maximum current. The bus bars shall be of drawn copper, 98 per cent pure, and shall run in horizontal and vertical directions only, with as few joints as possible. Where joints occur they are to be sweated and bolted, and the area of contact shall be at least 1 square inch per 180 amperes of current.

53. All connections to pilot lamps, indicating instruments, etc., are to be safely and neatly made and arranged on the back of the board. They are to be of braided, flexible, rubber-covered copper wire, 98 per cent pure, securely cleated to the board at intervals not greater than 1 foot, and all terminals are to be soldered to their wires or bus bars. All connections off the board are to be provided with suitable cast-copper terminal lugs.

54. *Generator switchboard.*—The panel of the generator switchboard shall be 5 feet 6 inches high, 2 feet 8 inches wide, and 1½ inches thick. The subbase shall be 1 foot high, 2 feet 8 inches wide, and 2 inches thick.

55. The following instruments and apparatus, with all the necessary connections, are to be furnished by the contractor and mounted upon this panel in the positions as shown on sketch:

56. Two pilot lamps, each consisting of a copper goose neck with Edison key-lamp socket and 115-volt 16-candlepower lamp, together with necessary wiring and cut-outs, and aluminum reflector suitably attached for concentrating the light from its lamp on the switchboard.

57. One voltmeter, 0 to 150; one ammeter, 0 to —— (50 per cent in excess of capacity of generator). These instruments are to be of the standard round-pattern form, with air-tight and moisture-proof iron cases, thoroughly nickel plated over copper, and secured to the panel by bronze or copper bolts with nickel-plated heads.

58. The instruments are to be of the movable-coil type, to be direct reading, with uniform scales; to be dead-beat without mechanical damper, and to have no magnetic lag.

59. The heating effect must be a minimum, and the temperature correction must not exceed 1 per cent for a change of temperature of 30° F. above or below normal.

60. The ammeter shall be of the shunt type, with external shunt inclosed in an air-tight and moisture-proof noncorrosive case. The part of the ammeter circuit between the shunt terminals and the terminals of the instrument, furnished by the maker and included in the calibration, must be of braided flexible rubber-covered copper wire, 98 per cent pure, similar to other connections.

61. One 4-point voltmeter switch. This switch shall be of the double-pole, circular type. Handle and pointer, with name plate marked with 4 points, are to be on front of board. Contact points to be mounted on a slate or marble base on back of board. Contact arm to be of some incombustible material absolutely unaffected by dampness or moisture, and to be so fastened to spindle that constant use will not loosen it. Contacts are to be sliding, with adjustable pressure and contact points slightly raised above surrounding insulating base, and so spaced that there will be no danger of the metal on the contact arm getting between and short-circuiting them.

62. One visible ground detector, to consist of two lamp receptacles placed as shown and connected as indicated, in series across the bus bars, with a ground connection between the receptacles, and two 115-volt 16-candlepower lamps.

63. —— —— ampere, double-pole, quick-break switches, with fuses. The conducting parts of switches and fuse terminals are to be constructed throughout of copper, 98 per cent pure, of ample size to give a current density not exceeding 800 amperes per square inch for drawn copper and 400 amperes per square inch for cast copper. The blades shall be of drawn copper, the contact leaves of sawed spring copper, firmly secured in milled slots in foot plates by sweating and riveting. In single-break switches the hinge bolts will be provided with spring washers to secure good contact between clips and blades. Insulation will be of hard rubber, handles of ebony, with through bolts to secure them firmly to switches. The bolts and screws may be made of bronze or brass, but no iron or steel will be permitted in the construction. Where fuses are called for, each blade of the switch will be provided with fuse terminals placed as shown, of the same capacity as the switches to which they are connected. The face of the switchboard under fuse terminals will be protected by sheet mica. The fuses must be of the inclosed type, with copper terminals, and are to be held in position by approved fastenings. ——— extra fuses for each switch will be furnished. The fuse terminals will be plainly marked with the capacity of the proper fuse for that circuit, which shall be about 25 per cent in excess of the normal current.

64. Where metals of different colors are used in the construction of the switches and fuse terminals, they will be copper plated and lacquered to give uniform color and finish.

65. The line terminal of switches on back of board will be provided with terminal lugs bored to receive stranded conductors of sizes corresponding to the capacities of the switches.

66. No switch of less capacity than 50 amperes will be used.

67. One single-pole magnetic overload circuit breaker, —— amperes capacity. This must be so designed and constructed that, with the minimum current necessary to operate the circuit breaker, the force

exerted on the actuating parts will cause it to positively open the switch under all conditions.

68. The electro-magnetic parts must be designed to develop more energy than is necessary to trip the retaining catch. This additional energy developed to accelerate the opening of the switch as the conditions approach those of short circuit. The adjustment must be effectual without the use of springs, preferably by means of weight through distance, and must be accurate and have a guaranteed constancy of action within 5 per cent of the adjustment. All parts must be easily accessible, and it must be supplied with a thoroughly insulated handle for manual operation.

69. One single-pole magnetic overload circuit breaker, —— amperes capacity, with underload attachment. This cut-out as an overload must correspond exactly to the above, and as an underload must positively open the circuit when the voltage of the generator at its brushes is below 75 volts. If closed when the voltage is below 75 it must not catch, but open automatically as soon as the closing force is removed.

70. In both overload and underload circuit breakers the conducting parts must be of drawn copper, 98 per cent pure, so proportioned that the current density of any part when carrying the normal current is not to exceed 800 amperes per square inch. No iron or steel parts shall be used except where they are required for magnetic conditions or mechanical strength, and when used they shall be thoroughly copper plated and lacquered, to prevent corrosion.

71. The retaining catch of trigger will be made of steel, casehardened, and must form no part of the circuit, and no insulation will be used in the construction of these parts. All bearing parts and pins likely to be affected by corrosion must be of phosphor bronze. All insulating material must be moisture proof and nonabsorbent. The metal parts are to be thoroughly copper plated and well lacquered, to secure uniform finish and to prevent corrosion. The main contacts are to be protected by auxiliary carbon contacts.

72. To insure certainty of action in releasing the retaining trigger, a free preliminary movement of the plunger or armature must precede such action and all working parts must be plainly visible. The circuit breakers will be supplied with threaded studs and flanged nuts for making the back connections on switchboard.

73. Two main fuses. Approved terminals to be placed as shown; and fuses to conform to the requirements given for fuses under the head of switches, and to have a capacity 50 per cent in excess of the rated capacity of the generator. ——— extra fuses will be furnished.

74. Field rheostat. The panel shall be bored to receive the field rheostat in accordance with drawings to be furnished by the United States, the hole for the spindle to occupy the position shown in sketch. This rheostat will be furnished with the generator.

75. *Accumulator switchboard.*—The panel of the accumulator switchboard shall be 5 feet 6 inches high, 3 feet 6 inches wide, and 1½ inches thick.

76. The subbase shall be 1 foot high, 3 feet 6 inches wide, and 2 inches thick.

77. The following instruments and apparatus, with all the necessary connections, are to be furnished by the contractor and mounted upon this panel in the positions as shown on sketch.

78. Three pilot lights, each consisting of a copper gooseneck with Edison key-lamp socket and 112-volt, 16-candlepower lamp, together with necessary wiring and cut-outs, and aluminum reflector suitably attached for concentrating the light from its lamp on the switchboard.

79. One voltmeter, 0 to 150; two double-reading ammeters, —— to 0 to ——. These instruments are to be of the standard round-pattern form, air-tight, and moisture proof, with iron cases, thoroughly nickel plated over copper, and secured to the panel by bronze or copper bolts with nickel-plated heads.

80. The instruments are to be of the movable coil type, to be direct reading, with uniform scales; to be dead-beat, without mechanical damper, and to have no magnetic lag.

81. The heating effect must be a minimum, and the temperature correction must not exceed 1 per cent for a change of temperature of 30° F. above or below normal.

82. The ammeters shall be of the shunt type, with external shunt inclosed in an air-tight and moisture-proof noncorrosive case. The part of the ammeter circuit between the shunt terminals and the terminals of the instrument, furnished by the maker and included in the calibration, must be of braided, flexible, rubber-covered copper wire, 98 per cent pure, similar to other connections.

83. One 6-point voltmeter switch. This switch shall be of the double-pole, circular type. Handle and pointer, with name plate marked with 6 points, are to be on front of board. Contact points to be mounted on a slate or marble base on back of board. Contact arm to be of some incombustible material absolutely unaffected by dampness or moisture, and to be so fastened to spindle that constant use will not loosen it. Contacts are to be sliding, with adjustable pressure, and contact points slightly raised above surrounding insulating base, and so spaced that there will be no danger of the metal on the contact arm getting between and short-circuiting them.

84. Two equalizing rheostats, to be mounted on back of the board for equalizing the charging current in the two parts of the accumulator. Each is to have the necessary resistance properly divided to give a total drop of 7.5 volts in ten equal steps of 0.75 volt each, when carrying a current of —— amperes (the normal charging current of the accumulator), and to have a carrying capacity of —— amperes (twice the normal discharge rate of the accumulator).

85. One regulating rheostat, to be mounted on back of board, for reducing and regulating the bus-bar voltage from 112 to that required in charging the accumulator when divided into two equal parts, in parallel, and also for regulating the bus-bar voltage during the discharge of the accumulator in series. The rheostat must have sufficient range and capacity to keep the charging current within 5 per cent of the specified normal through a charge of 2 to 2.5 volts per cell, with a constant voltage of 112 at the bus bars, and also to keep the variation of voltage at the bus bars within 1 volt throughout the entire discharge of the accumulator for all discharge rates from 10 to 200 per cent of the specified normal, and the resistance must be so proportioned that the change in voltage per step is approximately equal throughout.

86. All rheostats must be of some standard, well-known make, entirely self-contained, all connections being made within the rheostat, with no loose wires exposed to mechanical injury. They shall contain no solder, combustible or absorbent material, and no steel or iron except in frame or radiating surfaces. They must be as compact as possible and well ventilated, and the material of which the resistance coils are constructed must be such as will resist oxidation and not be injuriously affected by heating, They must be able to carry the maximum currents specified for them for four hours continuously, with a rise of temperature not exceeding 200° F. in any part, and an overload of 30 per cent for one minute without injurious heating.

87. The insulation between the current-carrying parts and the framework shall stand a test of 1,000 volts, alternating current, for five minutes without showing an appreciable leakage.

88. The contact arm and points shall be ample in size to prevent heating, with contact surfaces ground to fit, and when short-circuited with contact arm on the first point the current densities shall not exceed those specified for other connections.

89. The rheostats are to be provided on the front of the board with dials marked "Raise" and "Lower," to indicate the direction of motion, and handwheels of ample size to give sufficient leverage to operate the rheostats with ease; the handwheel of the regulating rheostat to have projecting spokes, as shown.

90. When necessary, a suitable support reaching to the floor and insulated therefrom will be provided, to relieve the strain upon the switchboard panel.

91. One double-pole magnetic overload circuit breaker, —— amperes capacity. It must be so designed and constructed that, with the minimum current necessary to operate the circuit breaker, the force exerted on the actuating parts will cause it to positively open switch under all conditions.

92. The electro-magnetic parts must be designed to develop more energy than is necessary to trip the retaining catch. This additional energy developed to accelerate the opening of the switch as the conditions approach those of a short circuit. The adjustment must be effectual without the use of springs, preferably by means of weight through distance, and must be accurate and have a guaranteed constancy of action within 5 per cent of the adjustment. All parts must be easily accessible. Both arms of the breaker shall be joined together by a yoke or bar, thoroughly insulated from them and supplied with a handle for manual operation.

93. One single-pole magnetic underload circuit breaker, with a carrying capacity of —— amperes. The cut-out must be so designed and constructed as to positively open the circuit when the current flowing through it falls below 5 amperes. If closed when no current is flowing through it, it must not catch, but open automatically as soon as the closing force is removed.

94. In both overload and underload circuit breakers the conducting parts must be of drawn copper, 98 per cent pure, so proportioned that the current density of any part when carrying the normal current is not to exceed 800 amperes per square inch. No iron or steel parts shall be used except where they are required for magnetic conditions or mechanical strength; and when used they shall be thoroughly copper plated and lacquered to prevent corrosion.

95. The retaining catch or trigger will be made of steel, casehardened, and must form no part of the circuit; and no insulation will be used in the construction of these parts. All bearing parts and pins likely to be affected by corrosion must be of phosphor bronze. All insulating material must be moisture proof and nonabsorbent. The metal parts are to be thoroughly copper plated and well lacquered to secure uniform finish and to prevent corrosion. The main contacts are to be protected by auxiliary carbon contacts.

96. To insure certainty of action in releasing the retaining trigger, a free preliminary movement of the plunger or armature must precede such action, and all working parts must be plainly visible. The circuit breakers will be supplied with threaded studs and flanged nuts for making the back connections on switchboard.

97. One —— ampere switch, triple-pole, double-break, double-throw.

98. —— 50-ampere switches, double-pole, quick-break, single-throw, with fuses.

99. (Insert number of larger switches.)

100. The conducting parts of switches and fuse terminals are to be constructed throughout of copper, 98 per cent pure, of ample size to

give a current density not exceeding 800 amperes per square inch for drawn copper, and 400 amperes per square inch for cast copper. The blades shall be of drawn copper, the contact leaves of sawed spring copper, firmly secured in milled slots in foot plates by sweating and riveting. In single-break switches the hinge bolts will be provided with spring washers to secure good contact between clips and blades. Insulation will be of hard rubber, handles of ebony, with through bolts to secure them firmly to switches. The bolts and screws may be made of bronze or brass, but no iron or steel will be permitted in the construction. Where fuses are called for, each blade of the switch will be provided with fuse terminals, placed as shown, of the same capacity as the switches to which they are connected. The face of switchboard under fuse terminals will be protected by sheet mica. The fuses must be of the inclosed type with copper terminals, and are to be held in position by approved fastenings. —— extra fuses for each switch will be furnished. The fuse terminals will be plainly marked with the capacity of the proper fuse for that circuit, which shall be about 25 per cent in excess of the normal current.

101. Where metals of different colors are used in the construction of the switches and fuse terminals, they will be copper plated and lacquered to give a uniform color and finish.

102. The line terminals of switches on back of board will be provided with terminal lugs bored to receive stranded conductors of sizes corresponding to the capacities of the switches. On front of board, above the triple-pole double-throw switch will be placed, as indicated, two bronze plates with black filled letters, marked, respectively, "Charge" and "Discharge," and above each feeder switch will be placed a small bronze plate with black filled letters, designating the particular circuit to which the switch belongs.

103. No switch of less than 50 amperes will be used.

SPECIFICATIONS FOR MOTORS.

104. There will be furnished the following motors:
—— motors of —— horsepower each to operate ——;
—— motors of —— horsepower each to operate ——;
—— motors of —— horsepower each to operate ——:
—— motors of —— horsepower each to operate ——.

105. These motors shall be compound wound with the series and shunt coils adjusted to the service required of each motor.

106. The motors must be entirely inclosed and practically moisture and dust proof. The frame will be provided with convenient hand-holes closed by covers with rubber gaskets.

107. Materials and workmanship must be of the highest grade throughout.

108. The armatures must be thoroughly ventilated, firmly secured on their shafts, well balanced, and run true. The shafts must have large bearing surfaces, have self-oiling and self-aligning bearings, and run cool.

109. The armature windings must be so arranged that the brushes in normal position shall be readily accessible through hand-holes provided with close-fitting covers with rubber gaskets and glazed peep-holes.

110. The commutator segments must be numerous and of pure copper, well insulated with mica of the proper hardness to wear at the same rate as the copper, and of ample depth for the capacity of the machine. There must be ample brush-working and radiating surface.

111. The rockers must have a fine adjustment. The brushes will be radial and of carbon, and —— extra sets shall be furnished. The brush holders must be so mounted that they can be readily adjusted and secured in position. There must be no sparking of the brushes when properly set between no load and 15 per cent overload. Plurality of brushes on each range is desirable.

112. The whole of the circuits to be of copper, of conductivity not less than 99 per cent of pure copper. The windings of both field and armature must be protected from mechanical injury, and must be painted with a water-excluding material. All insulation must be of materials absolutely unaffected by moisture, and all paints and varnishes used in the assembling and finishing of the machine must be selected with special reference to their moisture-proof qualities. The insulation resistance between circuits and between copper and iron parts must not be less than 1 megohm under the application of 1,000 volts of pressure.

113. The motor when completely inclosed must be capable of running continuously at its full-rated capacity for three hours without a rise of temperature in any part of over 50° C. above surrounding air, except commutator, in which the rise must not exceed 60° C. The heating of the coils shall be measured by the resistance method. The motor shall be designed to run at underloads with the maximum efficiency attainable in view of the full-load efficiency specified.

114. The efficiency of the motors shall be equal to the best commercial practice for the corresponding sizes.

115. Each motor will be provided with a suitable controller of sufficient capacity to reduce the speed of the motor — per cent for continuous working. The controller must fully meet all the general requirements for rheostats, and must be specially adapted to secure the desired service from the motor. The controller shall be provided

with automatic release for protection against both overload and underload, and shall be reversing if required.

SPECIFICATIONS FOR LAMPS.

116. *Efficiency.*—The lamps shall be of from 3.5 to 4 watts efficiency.

117. *Life and maintenance of candlepower.*—Lamps must show not less than 75 per cent of their initial candlepower after one thousand hours of service at 110 volts.

118. In testing for candlepower, the standard of luminous intensity shall be the British standard candle. The photometric test of lamps will be made at 110 volts, by revolving them at not less than 200 revolutions per minute, with axis vertical to obtain their mean horizontal intensity, with axis inclined 45° to obtain their mean spherical intensity, and with axis inclined 90° to obtain their vertical intensity. No lamp under these conditions shall show less than 15 candlepower, nor more than 17.5 candlepower mean horizontal, nor less than 13 candlepower mean spherical, nor less than 10 candlepower vertical intensity.

119. *Filaments.*—Filaments must be properly placed in the middle of the bulbs, and must not droop when turned horizontal during any portion of their life. Anchored filaments will not be considered.

120. When heated to a dull red, no spots, either dark or bright, shall appear.

121. *Bulbs.*—Bulbs must be uniform in shape and size, of molded lead glass, or equal, and free from defect. Tipless bulbs are preferred. The letters "U. S." shall be etched upon each bulb in such manner that they can not be removed.

122. *Bases.*—The Edison pattern short base will be furnished. Bases will be of good quality, firmly and accurately secured to the bulbs. The buttons will be of porcelain or other damp-proof material, and the interstices must be thoroughly filled and covered with shellac.

123. *Vacuum.*—All lamps must have a satisfactory vacuum. When tested on an induction coil delivering one-half-inch spark, the vacuum shall show no glow in the lamp.

124. Lamps failing to meet the requirements of these specifications will be rejected, and the failure of 10 per cent of any lot will be sufficient cause for the rejection of the entire lot.

SPECIFICATIONS FOR WIRE.

125. Wires shall be of soft annealed copper, heavily tinned, and shall have a conductivity of at least 98 per cent of that of pure copper; shall be covered with approved insulation three-thirty-seconds of an inch thick, protected by closely woven cotton braiding, which must

be thoroughly saturated with waterproofing material. The insulation must be sufficient to stand a potential of 3,500 volts, intermittently applied. The insulation resistance must be not less than 1,000 megohms per mile when tested after twenty-four hours in sea water and one minute's electrification, this test to be applied after the potential test.

126. All wires larger than No. 10, A. W. G., shall have stranded conductors.

127. One-half of the wire shall be furnished with black braiding, and one-half with white or red, to distinguish polarity.

128. Underground cables shall have conductors of soft annealed copper, 98 per cent pure, stranded at larger than 50,000 circular mils, heavily and evenly tinned, covered by an approved insulation five-thirty-seconds of an inch thick, and protected by a lead sheathing one-eighth of an inch thick, with a saturated fibrous covering over the lead. The insulation must be sufficient to stand a potential of 3,500 volts intermittently applied. The insulation resistance must not be less than 1,000 megohms per mile when tested after 24 hours in sea water and one minute's electrification; this test to be applied after the potential test.

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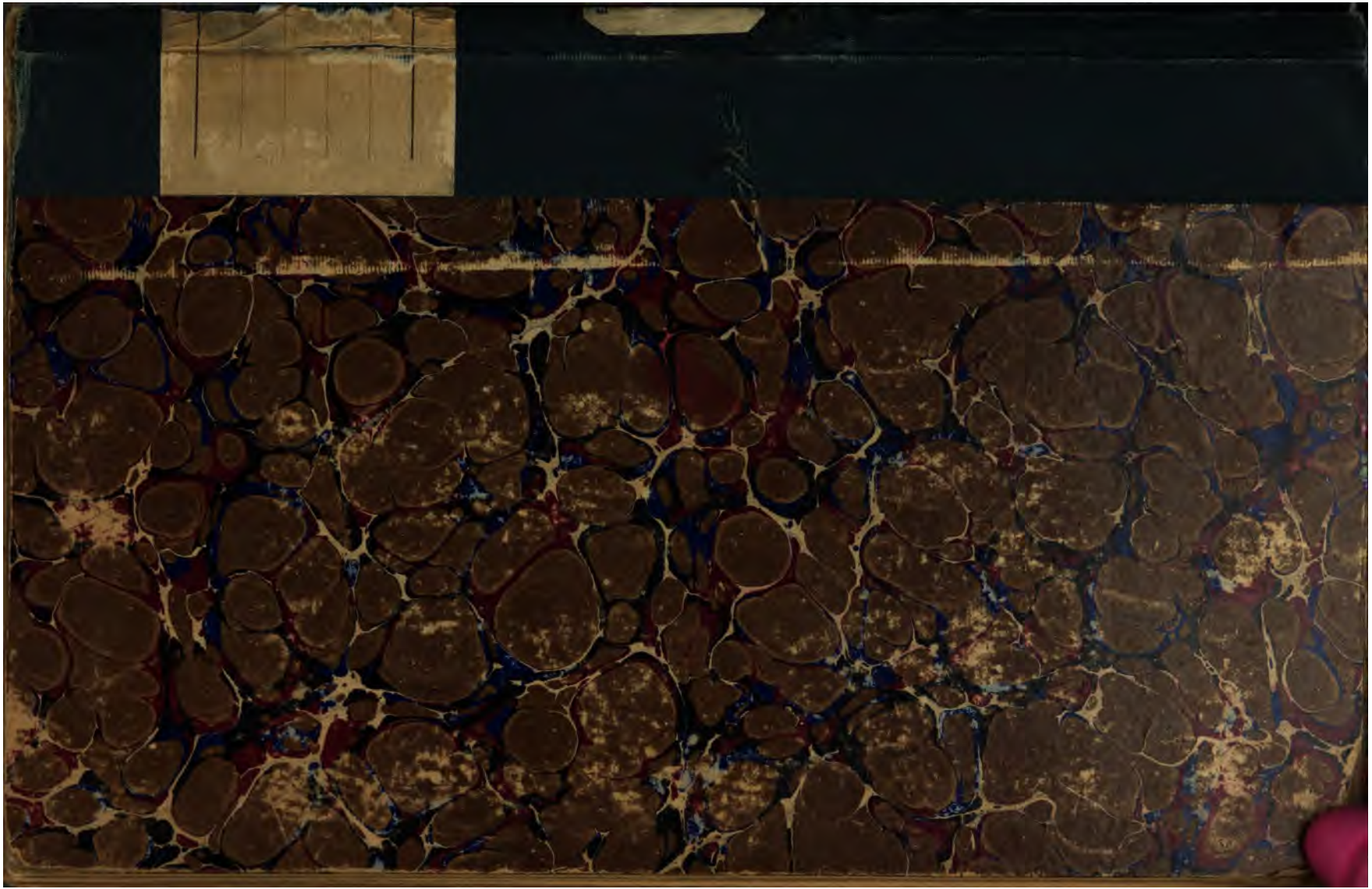
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